

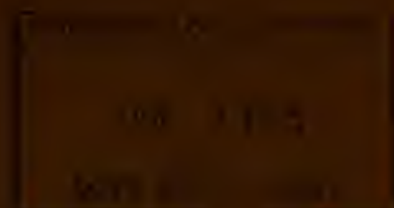
GEOLOGY AND ENGINEERING
GEOLOGIC ASPECTS OF THE
SAN JUAN CAPISTANO QUADRANGLE,
ORANGE COUNTY, CALIFORNIA

1974

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GEOLOGY AND ENGINEERING GEOLOGIC ASPECTS OF THE
SAN JUAN CAPISTRANO QUADRANGLE, ORANGE COUNTY,
CALIFORNIA

This report is based on work completed in 1972.

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SUMMARY AND RECCOMENDATIONS

The critical engineering and environmental geologic problems of the San Juan Capistrano quadrangle are summarized below in the approximate order of their overall importance.

1. *Slope stability* is a major problem in the quadrangle. Areas underlain by siltstones of the Capistrano, Monterey, and Topanga Formations are the most prone to slow-developing slump-type failures. Particular care should be exercised in the development of engineering works in the above rock units. Dangerous rapid-forming failures known as "rock-falls" develop in the resistant and cliff-forming strata of the San Onofre Breccia and Topanga Formation, especially during periods of intense rainfall. Slopes adjacent to developments should be inspected for this hazard even if they lie outside the actual project boundaries. Mud-debris flows constitute another dangerous rapid-forming slope failure which is prevalent during periods of intense rainfall. Areas most prone to this type of failure within the quadrangle are steep reentrant canyons which are underlain by the Oso Member of the Capistrano Formation, and to a lesser degree, the Sespe and Monterey Formations. (See Slope Stability.)
2. *Seismicity and active faulting* are hazards prevalent throughout California. The closest faults likely to produce earthquake damage in this area are the San Andreas, San Jacinto, Elsinore-Whittier, and Newport-Inglewood faults. The Cristianitos fault, which lies within the study area is of questionable activity and should be investigated further in the near future. Development of this area is taking place at a rapid rate. The most severe ground response can be expected to be on Quaternary alluvium, especially where the ground water level is within thirty feet of the surface.
3. *Expansive earth materials* are widespread in the area. Areas most affected by this phenomenon are those underlain by the Monterey and Capistrano Formations. Determination of expansivity and appropriate remedial measures should be required preceding construction in these areas. (See Table 1.)
4. *Erosion* is a maintenance problem which can be expected to be severe in many areas underlain by the Niguel Formation and friable sand strata of the Oso Member of the Capistrano Formation. (See Table 1.)
5. *Loss of significant mineral resources* in the form of sand and gravel resources in Trabuco and San Juan Creek drainages is probable unless more effective zoning ordinances are adopted. Joint flood control, settlement basins, and recreational lakes following mining operations could be considered in these areas. (See Mineral Resources Potential.)

6. *Tsunami (or "Tidal Wave") hazard* is a remote possibility which could affect the coastal portion of the quadrangle. Aliso Creek from its mouth to about one mile upstream could be affected by such an event.

INTRODUCTION

This study was undertaken in 1970-71 through a continuing cooperative agreement between the County of Orange (Road Department, Department of Building and Safety, and the Orange County Flood Control District) and the State of California, Division of Mines and Geology.

The purpose of the study is to provide sufficient geologic detail and insight so that development of the hillside areas of this quadrangle may progress with due consideration to which of the environmental geologic aspects of the terrain need additional detailed investigations.

Previous mapping of the area by Vedder, Schoellhamer, and Yerkes (1957) of the U.S. Geological Survey was relied upon heavily as the basis for mapping of the bedrock units. In order to stress engineering geologic aspects, and to consider numerous new exposures afforded by development in the area the geologic mapping was redone. The most significant new information are the Capistrano-Niguel, and San Onofre-Topanga formational contacts and delineation of landslides and other surficial units. Consultation and data generously provided by the above are gratefully acknowledged. Special acknowledgment is also given to F.G. McLellan, Jr., Cecil E. Hollon, and William R. Munson, of the Orange County Department of Building and Safety; Steve Stankov of the Orange County Road Department; Oscar Stankov of the California Division of Highways; Donald Asquith of F. Beach Leighton and Associates; Jackson Goffman of Evans, Goffman, and McCormick; Murray Patton of Boyle Engineering; and Glenn Miller and Richard Moyle of the U.S. Geological Survey.

Edward C. Wilson, Shelton P. Applegate, Hildergarde Howard, Wade Miller and David Whistler of Los Angeles County Museum provided paleontologic identifications.

Gordon Chase aided by Bert Jeffries of the Division of Mines and Geology contributed seismic refraction data on landslides; Paul Anderson also of this division supplied geochemical analyses.

Cooperation of the property owners in the area is gratefully acknowledged.

Field mapping was done directly on a U.S. Geological Survey topographic map base (1968 edition) enlarged to a scale of one to 12,000. Field observations were augmented by interpretation of aerial photographs taken in 1938, 1939, 1965, 1967, 1970 and 1971 at various scales. Several landslides were investigated by the use of seismic methods, and trenching was used to substantiate location of some faults. Laboratory

determinations by Paul Anderson were used to confirm the presence of notable amounts of phosphate and to determine purity of limestone in the Monterey Formation (See tables). A limited number of sieve analyses were provided by the County Road Department in order to check field determinations of grain size.

GEOLOGIC SETTING

The San Juan Capistrano quadrangle lies at the southeastern-most extremity of the Los Angeles basin. The alluvial deposits of the basin plain lie at the north border of the area and give way southward to rolling hills which form the coalescence of the Santa Ana Mountains on the east with the San Joaquin Hills on the west.

The quadrangle is underlain by Tertiary marine and nonmarine sedimentary strata ranging in age from late Eocene (?) through Pliocene. These are capped unconformably by Pleistocene and Holocene surficial units. The bedrock units from oldest to youngest are the Sespe Formation, reddish, silty arkosic sandstone; Vaqueros Formation, pale-yellowish-brown, silty arkosic sandstone; Topanga Formation, yellowish-gray, calcareous sandstone; San Onofre Breccia, massive, very coarse, reddish-brown schist-breccia; Monterey Formation, white, tuffaceous and diatomaceous siltstones; Capistrano Formation, yellowish-gray siltstone except in its Oso Member which is white, massive, silty sandstone; and the Niguel Formation, light-gray, friable sandstone.

The pre-Niguel Formation sedimentary sequence is gently folded into a broad north-trending syncline whose axis approximately bisects the area. The exposed central portion of the syncline is underlain mainly by the Capistrano Formation of late Miocene to early Pliocene age. Exposures on the east and west limbs of the structure are underlain by the successively older Monterey, San Onofre Breccia, Topanga, and Vaqueros Formations of Miocene age. Nonmarine deposits of the Sespe Formation of late Eocene (?) to early Miocene age crop out only in the northwestern part of the quadrangle. Late Pliocene sediments of the Niguel Formation, which postdate the synclinal structure, unconformably overlie and cap older formations and are flat-lying to gently dipping.

Surficial deposits representing a time span extending from perhaps early Pleistocene through Holocene time, cover a great percentage of the area. The oldest of these units consist of flat-lying nonmarine and marine terrace deposits. The remaining surficial units consist of older and younger alluvium of existing stream channels, slopewash and colluvial debris, beach sediments, landslide debris, and man-made fill materials. All of these Quaternary deposits are apparently undeformed.

Dominantly north and northwest-trending faults occur mainly along the east and west margins of the quadrangle. The largest of these is the Cristianitos fault zone along the northeast margin. The Shady Canyon fault and Laguna Canyon fault zone are located on the west margin; the Temple Hill fault, an east-trending fault, apparently terminates near Aliso Creek along the west margin.

The Cristianitos fault zone is a regional structural feature which extends northwestward from a few miles offshore near San Onofre to the northeast edge of this quadrangle and at least five miles beyond to the north for a total exposed distance of about 30 miles. The zone consists of a complex system of anastomosing shears with two principal branches in this area designated the west branch and main branch, which are as much as 2,000 feet apart. Both branches are vertical to steeply west-dipping normal faults with their east blocks uplifted relative to the west blocks. The total combined vertical separation in this area ranges from an estimated minimum of about 700 feet just north of Trabuco Creek to about 1,800 feet just south of Trabuco Creek. Trenching evidence indicates that Pleistocene river terrace gravels of Plano Trabuco (minimum age 34,000 years) are not cut by the main (east) branch of the fault; the west branch of the fault has not been sufficiently explored to determine its most recent activity (See Seismicity and Active Faulting below).

The Shady Canyon fault extends northwesterly for six miles through the northeast block of the San Joaquin Hills. The northeast side appears to have been uplifted at least 1,000 feet. The Topanga Formation is missing on the uplifted northeast block, suggesting that this side may have been a positive area during middle Miocene time. North of Wood Canyon the fault apparently offsets the lowermost beds of the Monterey Formation, but southeast of Wood Canyon the fault extends for an unknown distance beneath unfaulted younger Monterey, Capistrano and Niguel Formations.

The Laguna Canyon fault zone is a north-northwesterly trending complex fault zone crossing the southwest corner of the quadrangle, half a mile to three-fourths of a mile above the mouth of Aliso Creek. The fault zone is a major structural feature apparently extending at least 11 miles from the upper reaches of Laguna Canyon southward to South Laguna and the region of lower Arroyo Salada. Throughout most of this distance, the zone consists of two principal, nearly parallel, faults and numerous smaller, shears and subsidiary faults. The two major breaks appear to be normal faults having moderate to steep westerly dips with the western blocks apparently displaced downward relative to the eastern blocks. Within the quadrangle, however, the eastern fault is mapped with the western block displaced upward relative to the eastern block (Vedder, 1957 and Duggan, 1961), resulting in an apparent upthrown block between the two principal breaks of the fault zone. Stratigraphic control across the fault zone is too poor within the quadrangle, to determine the extent of displacement. Bode (1943) proposed an 1,850 foot vertical relative displacement across the zone north of the quadrangle in Laguna Beach near its junction with the Shady Canyon fault. Relative vertical movement south of the Temple Hill fault appears to be less than 1,850 feet but in excess of 200 feet.

The history of movement along the Laguna fault zone is poorly demonstrated by the geologic record. The youngest unit known to be displaced by the fault zone is the San Onofre Breccia of middle Miocene age. Pleistocene marine terrace deposits along the trace of the eastern principal break appear to be unaffected by the fault.

The Temple Hill fault is a west-trending fault extending from the mouth of Laguna Canyon eastward across Aliso Creek. Its junction with the Laguna Canyon fault zone, which it apparently displaces, is near the top of the ridge east of Laguna Beach and immediately west of the San Juan Capistrano quadrangle. The fault apparently dips from about 60 degrees south to nearly vertical with the apparent sense of movement up on the north block. Regional attitudes in the north block indicate that the fault is the southern boundary of moderately east-dipping sediments juxtaposed against a block of southerly dipping sediments. The amount of displacement across the fault is difficult to determine. The only exposed rock units cut by the fault are the Topanga Formation and a part of the San Onofre Breccia which are, in part, contemporary with each other. Lack of marker horizons precludes anything more than a very approximate sense of movement.

GEO-ENVIRONMENTAL PROBLEMS

Slope Stability

Slope stability in the San Juan Capistrano quadrangle as elsewhere is dependent on a multiplicity of factors and their interrelationships. Rock type and related pore-water characteristics are probably the most important of these, followed by steepness of slope due to undercutting. Lesser factors, but those which are locally important, are bedding, jointing, faulting and their geometry with reference to the topography.

Rainfall, earthquakes and man's activities are contributing factors independent of the bedrock geology; these are secondary factors but they amplify the effect of the primary failure factors already present.

Areally the higher incidence of landslides coincides in large measure with areas underlain by shale and siltstone. This is due to inherent lithologic properties such as high porosity and low cohesive strength when wet. Numerically, more slope failures have occurred in the Capistrano than in any other formation followed closely by the Monterey Formation and, to a lesser extent, the San Onofre Breccia and the Topanga Formation; far fewer landslides occur in the remaining bedrock units.

Landslide incidence determined by comparing the total area of exposure of a given formation to the area within it underlain by landslides follows the same general order.

A noteworthy observation concerning sizes of landslides is that most failures larger than about ten to 15 acres in extent are probably prehistoric as determined by degree of erosional modification of their geomorphic features. The only two dates available on these suggest that most larger landslides occurred from 10,000 to 20,000 years ago. One radiocarbon date obtained in this study was obtained from a carbon-rich soil horizon which was overridden by a large landslide in the NW. 1/4 of NW. 1/4 of sec. 32, T. 7 S., R. 7 W. This sample indicated an age of 10,880 $\pm$ 160 years B.P. (Teledyne Isotopes). A second date by Stout (1969, p. 173) for a landslide located in the

SW. 1/4 of NW. 1/4 of sec. 8, T. 8 S., R. 7 W., immediately southwest of the San Juan Capistrano quadrangle was dated at 17,180 $\pm$ 750 years B.P. Both of these landslides occurred in the Capistrano Formation.

It is likely that widespread landsliding during this period in time was partly a function of climatic change from sub-humid to semi-arid conditions. Estimated rainfall for the period 14,000 to 15,000 years B.P. is more than double present day figures (Stout, 1969, p. 175). The implication of these observations is that with increased water influx, either natural or due to urbanization, we might expect increased incidence and extent of landsliding unless adequate control measures are exercised.

Siltstone, silty claystone and claystone, diatomaceous shale, and tuffaceous shale, common in the Capistrano, Monterey, and Topanga Formations have moderately high to very high porosities and are, therefore, capable of very high moisture retention. High moisture retention increases density of such materials as much as 1 1/2 to two times. Furthermore, high moisture content increases the probability of plastic flow; even liquidity under more severe moisture conditions can occur. Increased weight and plasticity obviously affect slope stability. Determination of Atterberg limits is useful in the evaluation of specific sites for slope stability.

Instability of inherently weak fine-grained materials due to high moisture content is amplified in the thinly bedded, fissile Monterey Formation, and in the extensively jointed Capistrano Formation. Where these planes of weakness dip in the same direction as the slope of the surface, the propensity for failure is greater. This is especially so if the planes of weakness are "daylighted" that is, inclined out of slope at less than slope angle.

The role of earthquakes and landslides has been amply demonstrated in Alaska in 1964 and in Chile in 1970. Clearly earthquakes provide additional stresses that may trigger failures of slopes already inherently unstable.

Rockfall and mud-debris flows are particularly critical slope stability problems because they occur rapidly, without warning, and are very destructive to anything in their path. Rockfall is most likely during periods of intense rainfall or seismic shaking, although it can occur at any time due to normal erosional processes. Areas most susceptible to rockfall are below steep resistant outcrops of well-indurated material. Such material is most common in the Topanga Formation and the San Onofre Breccia. Some areas along Wood Canyon, lower Aliso Creek, and their tributaries are particularly vulnerable.

Mud-debris flow hazards within the quadrangle are greatest in the Oso Member of the Capistrano Formation. Mud-debris flow activity is widespread during exceptionally high rainfall periods, and occurs mainly at the heads of steep canyons. Mudflows are common also in the Sespe and Monterey Formations.

Units highly susceptible to rilling, ravelling and wind erosion are the sand facies of the Niguel Formation and friable interbeds in the Oso Member of the Capistrano Formation. Capistrano Formation siltstones are particularly prone to piping (development of subsurface open drainage passages along joints and fractures).

Seismicity and Active Faulting

The San Juan Capistrano quadrangle, as all of the State of California, lies within a seismically active belt that rings the Pacific Ocean. Any discussion of seismicity must consider its regional aspects inasmuch as large magnitude earthquakes affect areas many times the size of this quadrangle.

Large earthquakes of magnitudes 7.0 and greater can be expected to occur along at least one of the great earthquake producing faults of the southern California region within a period equivalent to that of the historic record. The historic record, though fragmentary, began in 1769. The most likely earthquake generating faults in the region, together with their closest proximity to the mapped area are the San Andreas (43 miles), San Jacinto (35 miles), Elsinore-Whittier (12 miles), and the Newport-Inglewood (two miles). A less significant fault suggested to be active within the range of influence is the Norwalk fault which lies about ten miles to the north (Richter, 1958). The seismic hazard of the Cristianitos fault zone is open to question at this time (see below).

Large shocks originating within a fifty-mile radius of this quadrangle could cause high intensity response within the quadrangle. What intensity this might reach is not possible to predict at this time, but ground response would be greatest in the mostly unconsolidated Quaternary-aged deposits, especially where ground water levels are within 30 feet of the surface (Meidav, 1966). Next most vulnerable would be the Tertiary sedimentary rocks that are steeply dipping, followed by flatter lying strata. Interfaces between rocks of contrasting induration are more susceptible to adverse response than homogeneous materials; therefore, building astride contact zones between grossly different rock types should be avoided where possible for critical structures (i.e., hospitals, schools, dams) unless these structures are designed to survive the effect of differing ground response across such areas.

Some degree of differential settlement and possibly liquefaction can be expected in alluvium and slopewash due to severe shaking. Shaking may also trigger rockfall in cliff-forming materials, and bedrock landslides in rock units which are most susceptible to such failures (See Slope Stability).

Four instrumentally recorded small epicenters have been recorded within the quadrangle (see geologic map). All were less than a magnitude of 3.0 and were recorded in 1937 and 1948. Epicenters of magnitude 5.5 and 4.5 with numerous aftershocks have been recorded in

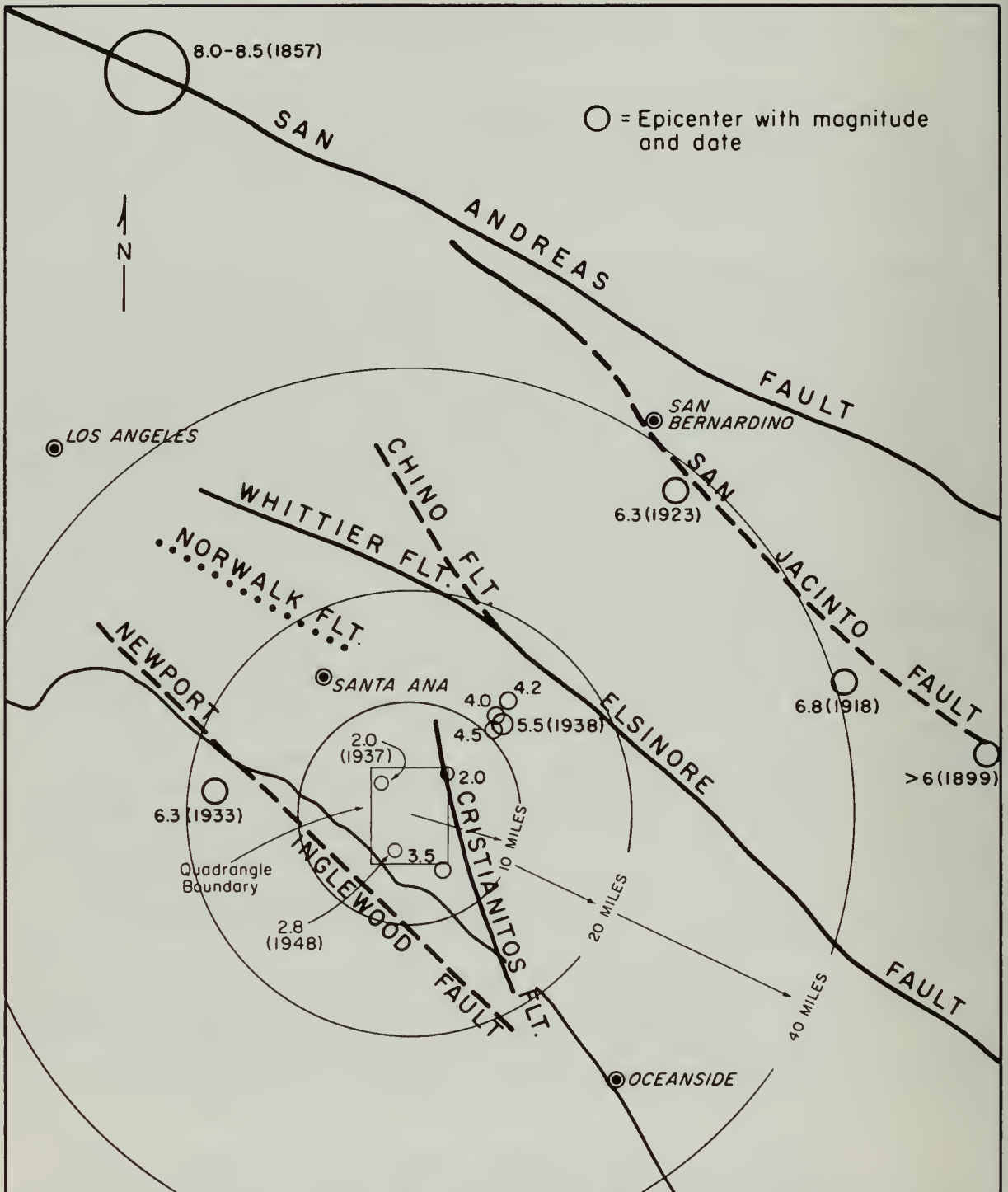


Figure 1. REGIONAL SEISMICITY, SAN JUAN CAPISTRANO QUADRANGLE

an area centered about eight miles to the northeast in the upper Trabuco Canyon area in May, June and July, 1938 (written communication, California Institute of Technology, Seismological Laboratory, unpublished records).

A summary of historic earthquakes that may have caused structural damage in the area are listed in the table below.

Only one of the faults mapped in the area was found to have any evidence suggesting Quaternary-age displacement. The Cristianitos fault zone, which traverses the eastern edge of the quadrangle, was examined closely during this study in order to evaluate recency of movement. No definitive evidence was found within the quadrangle to establish movement since deposition of Pleistocene river terrace deposits of Trabuco Canyon drainage. A bulldozer trench in Tijera's Creek along the main or eastern trace of the fault was excavated by the Southern California Edison Company in 1969. This excavation demonstrated no disruption of the terrace materials by the main branch of the fault. Attempts to expose other traces at that time were unsuccessful. However, a back-hoe trench placed in 1971 by the Division of Mines and Geology about two miles farther to the south in the San Juan Capistrano quadrangle succeeded in exposing a western branch of the fault. This trench showed apparent displacement of a two-foot thick slopewash cover along two shears a few feet apart. Maximum dislocation of the soil-bedrock interface was approximately two feet. As this evidence suggested possible late Holocene movement, additional trenching was placed in the same area by the Southern California Edison Company in June, 1972 in order to check this possibility. These excavations suggested that the apparent displacement of the soil cover may have been due to a combination of animal borings and differential erosion of the bedrock surface with subsequent soil deposition. However, Holocene movement has not been ruled out. To satisfactorily resolve the problem the authors believe that additional trenches exposing the base of Holocene alluvium are necessary.

Three of the four epicenters that plot within the quadrangle can reasonably be attributed to the Cristianitos fault zone, though this is not necessarily true (see geologic map). This possibility in itself is neither proof nor disproof of activity on the Cristianitos fault zone, but is offered here merely as additional data to be considered.

MINERAL RESOURCE POTENTIAL

The mineral resources of commercial potential in the San Juan Capistrano quadrangle are sand and gravel, petroleum and possibly for specialty sands, phosphates, decorative stone, and limestone.

Sand and gravel are presently being mined by Livingston-Graham, Inc. from Quaternary alluvium in Trabuco Creek. This operation has been mined for many years and shallow reserves in the existing lease areas are nearly depleted. Additional mineable material exists upstream and possibly underlying existing pits.

Fig. 2 HISTORIC EARTHQUAKES POTENTIALLY DAMAGING TO STRUCTURES IN THE SAN JUAN CAPISTRANO QUADRANGLE

<u>Date</u>	<u>Approximate area of origin</u>	<u>Modified Mercalli Intensity Near Origin</u>	<u>Magnitude</u>
1769, July 28	Not known but noted by Portola expedition near mouth of Santa Ana Canyon	?	?
1812, December 8	Not known but severely damaged Missions San Juan Capistrano and Santa Ynez	IX-X	7 *
1857, January 9	Fort Tejon region	X-XI	8.0*
1892, February	Baja, California	?	7.0*
1893, April 4	Newhall	VIII-IX	?
1899, December 25	San Jacinto-Hemet	IX	7.0*
1918, April 21	San Jacinto-Hemet	IX	7.0*
1923	San Bernardino	?	6.0*
1933, March 10	Long Beach (offshore)	IX	6.3*
1938, May 31	Santa Ana Mtns. (Upper Trabuco Canyon)	VI	5.5
1956, January 3	Glen Ivy (Riverside Co.)	VI	4.7

*estimated magnitude

Both the existing operations and the upstream extension are under restrictive pressure from immediately adjacent newly developed residential housing in Mission Viejo. Restrictions concerning dust, hot plant vapors, truck traffic, noise and other environmental considerations could prevent efficient extraction of much of the remaining deposits. Sequential-use development may prevent loss of this valuable economic resource.

A coordinated mining-flood-control-recreation plan for this drainage course would be beneficial to all concerned. Newly developed areas downstream from the existing plant site are presently poorly protected from a "fifty-year storm." 1969 flood waters (a 35-year storm) were barely contained in the channel along the southeast bank of the river upstream from the San Diego Freeway. The well-being of the community would be well served if a sequential-use plan could be developed that would provide for (1) mining of the deposit until depletion (2) provision for tax revenues that result from the operation to be used for development of the mining area for recreational use (3) a below-river-grade basin, developed by the mining process, to provide partial retention of disastrous runoff of periodic flood water (4) use of the area for recreational purposes following the main mining operation (5) short mining periods following natural replenishment of sand and gravel by periodic storms (6) use of the area for recreation during non-mining periods.

Such a plan would of course require a detailed study by all parties who would be involved with the plan. It is offered here simply as one alternative to loss of a mineral resource.

Petroleum possibilities in the San Juan Capistrano quadrangle have been investigated by several companies in the past (see map for drill-hole locations). Some potential does remain, however. Fault-trap closure is probable along the west side of the Cristianitos fault and in the complexly faulted areas underlying the western part of the quadrangle. Upper Cretaceous strata of the Schulz Ranch Member of the Williams Formation, which is most likely present in the subsurface areas of the quadrangle, has yielded small production from the Cristianitos and San Clemente fields a few miles to the south and east.

Friable, clean, white sands in some parts of the Niguel Formation and in the Oso Member of the Capistrano Formation offer limited and not fully assessed possibilities for specialty sands. However, because these materials lie in areas scheduled for early development for urban uses, their potential is here considered low.

Abundant phosphatic nodules and phosphatic shales occur in beds of the Monterey Formation in the vicinity of Aliso Creek about two miles northwest of Sulfur Creek Reservoir. Grab samples analyzed during this study contained a P_2O_5 content of 20-40%. Economic development of these deposits is unlikely because of rapid urban development and spotty occurrence of the material.

Decorative landscaping stone is available as boulders from some parts of the San Onofre Breccia. These boulders, which would otherwise pose a disposal problem to developers, can be recovered from large grading operations in terrain underlain by that rock unit. Mining just for the purpose of obtaining this material probably would not be economically feasible because the percentage of suitable material is low.

Small bodies of limestone containing as much as 50,000 tons of 93-99% CaCO_3 occur in lower beds of the Monterey Formation in the area just west of Moulton Parkway, south of El Toro Road, and northwest of Aliso Creek (denoted Tm-tls and Tm-ls on map). These deposits were the source for the unsuccessful Marine Shell Fertilizer Company during 1922-23 (Tucker, 1925, p. 68). Economic development of these deposits is unlikely in the future because of rapid urban encroachment and too scattered occurrences of relatively small masses of material.

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EXPLANATION SHEET OF CATEGORIES IN TABLE 1 - ROCK UNIT
CHARACTERISTICSFORMATION AND SYMBOL

TERRAIN FEATURES

Topographic expression	Each geologic unit weathers and erodes in its own characteristic way resulting in certain overall expression unique to itself.
Vegetation	Type of vegetation naturally occurring on this rock unit. Water retention and root foundation strongly influence support of and type of flora.
Approximate natural slope angle range	Normal range. Deviations from this norm do occur, of course, in every formation.
Slopewash development	Degree to which weathered disintegrated debris from the unit tends to accumulate and its nature.
Soil development	Type and extent characteristic to the formation. Identifications are from U.S. Soil Conservation Service maps.

LITHOLOGIC FEATURES

Type and color	Predominant rock types listed in order of abundance. Color designations are according to the Munsell System Rock Color Chart. (See Goddard, et al. 1951)
Bedding	Degree and character of development of planar arrangement of sediments resulting from original depositional mode of accumulation.
Induration and/or consolidation	Relative degree of hardness or compaction and character of cementation if present.
Angularity	An approximation of the average degree of angularity or roundness of grains and clasts occurring in the unit.

Sorting	Relative degree of similarity in size of individual grains occurring in the sediments (e.g. well-sorted indicates all particles are similar in size).
Composition	General composition. No exhaustive analyses were attempted.
Structure	Arrangement or configuration of bedding, jointing, fractures or other linear features of rock units.
Thickness	Maximum dimension of accumulation of the unit measured perpendicular to the bedding.
Contact relations	Nature of the interface between contiguous rock units.
Age and fossils	Geologic age and significant fossil occurrences.

ENGINEERING FEATURES

Unified soil classification	Size classification of grains and clasts occurring in a sediment if the material is in a disaggregated state. (As adopted by the Corps of Engineers and Bureau of Reclamation)
Workability	Ease of excavation by commonly used contemporary equipment.
Slope stability	Propensity of the rock unit to slope failure of various types.
Permeability	Empirical designation* of relative ease of water movement through the rock unit based upon visual inspection.
Porosity	Empirical designation* of relative degree of water absorption capability based upon visual inspection.
Density	Relative weight per unit volume. (Dry density where range is given)

Expansivity	Empirical designation* of relative degree of expansion when wetted.
Fabric	Structural grain imparted to the materials as a whole by arrangement of linear or planar elements such as beds, joints, fractures, texture, mineral grains, etc.
Erodibility	Relative degree of susceptibility to erosion.
Other	—

USE POTENTIAL

Sand and gravel	Amenability for use as aggregate or road base.
Fill	Amenability for use as fill materials of various types.
Waste disposal sites	General evaluation of the gross aspects of the formation relative to siting of solid waste disposal sites.
Aquifer	Evaluation of potential as a reservoir rock for ground water.
Other	Possible or suggested commercial mineral resource potential of materials within the rock unit.

*Note: "very high," "high," "Moderately high," etc., are empirical designations of rank used. More precise data were not available for this study.

TABLE 1

ALLUVIUM (QAL, QAL₁, QAL₂)

TERRAIN FEATURES

Topographic expression	Occurs only in present drainage channels and flood plains.
Vegetation	Oak, sycamore, willow, wild tobacco and annual grasses. Qal ₁ is extensively cultivated in rowcrops and citrus.
Approximate natural slope angle range	0° to 3°, excepting channel cut banks.
Slopewash development	Absent.
Soil development	Absent on Qal ₂ . 1' to 2' of mostly sandy loam to clayey loam on Qal ₁ . (Carpenter and Storie, 1929)

LITHOLOGIC FEATURES

Type and color	Light-gray to yellowish-gray, fine to coarse sand and gravel.
Bedding	Crossbedded and lenticular.
Induration	Unconsolidated to poorly consolidated.
Angularity	Mostly angular to subangular sand with subangular to rounded gravel fraction.
Sorting	Poorly sorted overall, but variable.
Composition	Quartzo-felspathic lithic sand with clasts composed mainly of eastern bedrock complex materials of the Santa Ana Mountains. Locally high percentages of western bedrock complex materials especially in the San Joaquin Hills.
Structure	Flat-lying.
Thickness	Highly variable but reaches as much as 175' in San Juan Creek; 125' in Trabuco Creek; 100' (?) in Aliso Creek.

Contact relations	Rests in channels cut on bedrock units.
Age	Holocene.

ENGINEERING FEATURES

Unified soil classification	Highly variable but mostly GW, GM. SM.
Workability	Easily excavated with light equipment.
Slope stability	Poor in Qal ₂ to fair on moderate slopes for Qal ₁ .
Permeability	Very high in major drainages to medium in tributaries.
Porosity	Variable but generally moderately high.
Density	Variable. Ranges from about 90 P.C.F. for SM to 120 P.C.F. for GW.
Expansivity	Negligible to low.
Fabric	Negligible.
Erodibility	Very high on slopes greater than 5°.
Other	—

USE POTENTIAL

Sand and gravel	High in Trabuco and San Juan Creeks. Low elsewhere.
Fill	High for pervious fill in major drainages.
Waste disposal sites	Low, due to ground water mobility and resultant pollution.
Aquifer	High.
Other	—

SLOPEWASH DEBRIS (Qsw)

TERRAIN FEATURES

Topographic expression	Broad gently inclined aprons at or near the base of slopes.
Vegetation	Tends to reflect characteristics of bedrock source.
Approximate nature slope angle range	Generally 1 to 10°.
Slopewash development	—
Soil development	—

LITHOLOGIC FEATURES

Type and color	Variable. Reflects bedrock source (see under bedrock units).
Bedding	Absent.
Induration	Unconsolidated.
Angularity	Variable. Reflects bedrock source generally.
Sorting	Variable. Reflects bedrock source generally.
Composition	Variable. Reflects bedrock source generally. Contains moderate organic debris.
Structure	Absent.
Thickness	Ranges from barely perceptible to as much as 30'. Thickest at base of slopes.
Contact relations	Mantles bedrock at and near base of slopes.
Age	Holocene.

ENGINEERING FEATURES

Unified soil classification	Variable. Reflects bedrock source.
Workability	Easily excavated.
Slope stability	Poor. Subject to slump, mudflow and creep on moderate slopes.
Permeability	Moderate to high depending on bedrock source.
Porosity	Variable. Reflects bedrock source.
Density	Low.
Expansivity	Variable but tends to be higher than bedrock source.
Fabric	Absent.
Erodibility	High on moderate or steeper slopes.
Other	—

USE POTENTIAL

Sand and gravel	None.
Fill	Low unless blended.
Waste disposal sites	Low due to thinness and proximity to ground water courses.
Aquifer	Low and limited in extent.
Other	—

BEACH SEDIMENTS (GB)

TERRAIN FEATURES

Topographic expression	Flat to very low gentle slopes at ocean shoreline.
Vegetation	Barren.
Approximate natural slope angle range	0° - 5°.
Slopewash development	None.
Soil development	None.

LITHOLOGIC FEATURES

Type and color	Light-gray, yellowish-gray, pale-yellowish-brown, pale-dusky-yellow sand, silty sand and minor gravel.
Bedding	Lenticular and poorly developed.
Induration	Unconsolidated.
Angularity	Subrounded to rounded.
Sorting	Moderately well to well sorted.
Composition	Predominantly quartz, feldspars and quartzite with some lithic grains and, locally, gravel.
Structure	—
Thickness	Very thin to a few tens of feet on well developed beaches.
Contact relations	Unconformable on older units.
Age	Holocene

ENGINEERING FEATURES

Unified soil classification	SP, SM, locally GP, G ₁ .
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Workability	Easily grades; moderately difficult where saturated.
Slope stability	Very poor, especially where saturated.
Permeability	High.
Porosity	Moderately high to high.
Density	Moderately high for unconsolidated sediments.
Expansivity	Nonexpansive.
Fabric	None.
Erodibility	Easily eroded by wind and water.
Other	—

USE POTENTIAL

Sand and gravel	Low; limited amounts and generally unavailable due to location.
Fill	Low; limited amounts, poor compaction characteristics. Good for pervious fill but generally unavailable due to location and need for retention on beaches.
Waste disposal sites	None, due to location, permeability and size of deposits.
Aquifer	Low, due to location and size of deposits.
Other	—

LANDSLIDE DEBRIS (QLs)

TERRAIN FEATURES

Topographic expression	Hummocky, subdued terrain, commonly with abrupt rise on upslope boundary; lower and lateral boundaries commonly crowd, divert, or block drainage; commonly contains undrained depressions.
Vegetation	Commonly grassy with abundant mustard and wild tobacco. Phreatophytes common near base.
Approximate natural slope angle range	Variable but less than surrounding terrain.
Slopewash development	Rapid accumulation of slopewash on to and from landslides after failure; drainage channels below older slides commonly choked with debris eroded from slide materials.
Soil development	Depth of soil on ancient landslides commonly is much thicker than on natural bedrock areas due to increased fracturing and heavy influx of slopewash.

LITHOLOGIC FEATURES

Type and color	Highly variable according to bedrock source.
Bedding	Absent. Undrained depressions commonly contain well bedded but thin clayey materials.
Induration	Very poor in most recent slides to moderately poor in ancient slides.
Angularity	Very angular to blocky except in block-glide slides which tend to remain semi-coherent.
Sorting	—

Composition	Depends wholly on source rock.
Structure	Generally chaotic except in block-glides. Highly plastic materials such as Monterey shales subject to tight, contorted folding.
Thickness	Variable.
Contact relations	Variable but generally gently to moderately inclined, broadly planar or semi-concave in configuration with thin clayey-gauge along failure surface.
Age	Holocene to Pleistocene.

ENGINEERING FEATURES

Unified soil classification	Variable.
Workability	Easily excavated with light power equipment. Failures containing well cemented materials may contain large boulders.
Slope stability	Highly susceptible to creep, slump, mudflow and renewed movement especially if undercut near toe or subject to high influx of water or loading by fill. Ancient slides tend to be less susceptible to renewed movement than recent slides.
Permeability	Generally high.
Porosity	High.
Density	Variable but generally low.
Expansivity	Commonly expansive where derived from clayey bedrock.
Fabric	Generally absent.
Erodibility	Very high.
Other	Crown area above recent landslides is commonly unstable.

USE POTENTIAL

Sand and gravel	Very low.
Fill	Variable depending on bedrock source (unloading toe portion of slide can trigger renewed movement).
Waste disposal sites	Very large landslides may be readily adaptable for class II and III waste if carefully planned.
Aquifer	Commonly a limited source of ground water. Springs commonly occur at the base of larger slides.
Other	Large landslides which are economically undevelopable for many uses may have limited use for recreational areas that do not require extensive grading or irrigation, i.e., stables, motorcycle courses, nature areas, etc.

OLDER ALLUVIUM (QoAL)

TERRAIN FEATURES

Topographic expression	Slightly elevated benches adjacent to Qal in major drainages.
Vegetation	Predominantly grasses.
Approximate natural slope angle range	1° to 8° except in channel cut-banks.
Slopewash development	Minimal.
Soil development	Minimal.

LITHOLOGIC FEATURES

Type and color	Pale-yellow-brown to yellow-gray sandy silt and minor pebbly sand.
Bedding	Crudely bedded and crossbedded.
Induration	Uncemented, moderately consolidated.
Angularity	Coarse fraction subangular (sand) to rounded (pebbles).
Sorting	Poor.
Composition	Derived mainly from Capistrano and Monterey Formation siltstones and Niguel Formation conglomeratic sandstone.
Structure	Essentially flat to gentle dips in crossbeds.
Thickness	Generally less than 25'.
Contact relations	Gently inclined towards and downstream of existing drainage channel.
Age	Early Holocene or Pleistocene.

ENGINEERING FEATURES

Unified soil classification	ML, SC with minor GM.
Workability	Easily excavated with light power equipment.
Slope stability	Moderately stable unless excavated into greater than 3:1 slopes.
Permeability	Moderately impermeable.
Porosity	Moderate.
Density	Moderately low.
Expansivity	Slight.

Fabric	Limited to crude bedding characteristics.
Erodibility	High.
Other	—

USE POTENTIAL

Sand and gravel	Very low.
Fill	Suitable for impervious fill.
Waste disposal sites	Very low due to proximity to principal drainage.
Aquifer	Very low.
Other	Very limited in areal extent.

NONMARINE TERRACE DEPOSITS (UNDIVIDED) (QT)

TERRAIN FEATURES

Topographic expression	Low, rounded, flat-topped terrain with moderately well developed dendritic drainage.
Vegetation	Grass.
Approximate natural slope angle range	0° to 5°.
Slopewash development	Thin on conglomeratic beds; greater than 3' on fine grained beds where it is generally expansive.
Soil development	Commonly greater than 3' on fine-grained beds. Sandy loam to loam (Soil Conservation Service, 1966).

LITHOLOGIC FEATURES

Type and color	Interbedded grayish-yellow to light-brown sandy silt, clayey sand and conglomeratic coarse-grained sand, also occasional buried clayey soil horizons.
Bedding	Thick to locally thin-bedded and occasional crossbedded channel sand.
Induration	Poor to moderate.
Angularity	Subangular to rounded.
Sorting	Poorly sorted to well sorted.
Composition	Arkosic sand; granitic and metavolcanic clasts of the eastern bedrock complex of Woodford, 1925. Commonly reflects the composition of surrounding formations such as Tc and Tn when derived from them.
Structure	Generally flat-lying or with gentle dips and crossbeds.
Thickness	Probably exceeds 150' in the northwest part of the quadrangle.
Contact relations	Unconformably overlies older formations in the quadrangle.
Age	Radiocarbon dates indicate much of the terrace deposits are greater than 32,600 years old (Gail Hunt of Southern California Edison Company, personal communication 1969); deposits at the Costeau Pit are slightly older than the Rancho La Brea stage of the late Pleistocene (Miller, 1971).

ENGINEERING FEATURES

Unified soil classification	Principally SW, SM, SC and CL with minor GM, GC and ML.
Workability	Easily removed with power equipment.

Slope stability	Generally good because of its low relief and flat-lying beds.
Permeability	Low to locally high.
Porosity	Low to locally high.
Density	Low to moderately high where conglomeratic.
Expansivity	Mostly low; buried soil zones commonly expansive.
Fabric	Minimal.
Erodibility	Very susceptible to gullying and rill erosion.
Other	—

USE POTENTIAL

Sand and gravel	Low potential; generally excessive fines and low clast percentage.
Fill	Good.
Waste disposal sites	Low, due to proximity to ground water aquifers, variable permeability and thinness.
Aquifer	Minor potential; generally too thin.
Other	—

RIVER TERRACE DEPOSITS OF SAN JUAN AND TRABUCO CREEKS (Q_{Tr})

TERRAIN FEATURES

Topographic expression	Bench-like platform areas flanking Trabuco, San Juan, and other large drainages.
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Vegetation	Largely grass covered with some low brush.
Approximate natural slope angle range	1° to 45°.
Slopewash development	Contributes moderate amounts of cobbly, silty slopewash on steeper slopes.
Soil development	Fairly well developed clay loam on flatter slopes.

LITHOLOGIC FEATURES

Type and color	Pale-reddish-brown to yellow-brown, silty to clayey gravel, and clayey silt and sand lenses.
Bedding	Crudely bedded and crossbedded reflecting irregular river channel filling and cutting.
Induration	Poorly cemented but well consolidated.
Angularity	All degrees of angularity.
Sorting	Very poor; generally with locally well sorted lenses. Average size of clasts 1" to 4" but range to 1' boulders.
Composition	Strongly lithic, clayey, quartzo-feldspathic matrix. Clasts reflect eastern bedrock source (metasedimentary, metavolcanic rock and weathered granodiorite and tonolite).
Structure	Flat to very gently dipping.
Thickness	Generally less than 40' but mid-channel deposits may be as much as 150' thick near Plano Trabuco.
Contact relations	Lower contacts dip gently towards canyon bottom. Some sharp channeling may occur near Plano Trabuco. Overlain only by Qsw and locally by Qal.
Age	C ₁₄ date on material at Plano Trabuco near the Cristianitos fault was dated as greater than 32,600 years (Pleistocene) (Gail Hunt of Southern California Edison Company, oral communication, 1969).

ENGINEERING FEATURES

Unified soil classification	GM, GC with minor SM, SC.
Workability	Moderately easily excavated with ripper-equipped heavy power equipment.
Slope stability	Generally quite stable; will stand in vertical cuts but subject to rockfall failures under these conditions. Steep stream cut-banks subject to rockfall failures.
Permeability	Moderately low.
Porosity	Moderately low.
Density	Medium to moderately high for sedimentary materials. (120-145 P.C.F.)
Expansivity	Residual soils expansible. Clayey silts slake readily.
Fabric	Minimal. Reacts massively.
Erodibility	Moderately low.
Other	Caution should be exercised near steep stream cut-banks and near contacts with Monterey and Capistrano Formations.

USE POTENTIAL

Sand and gravel	Low due to excessive fines. Clasts are sound.
Fill	Good where relatively low permeability is permissible.
Waste disposal sites	Low because of proximity to main drainage and relative thinness of unit.
Aquifer	Low.
Other	—

NONMARINE TERRACE DEPOSITS ON MARINE TERRACES (Q_{TN})

TERRAIN FEATURES

Topographic expression	Level to gently sloping with some local relief due to steep-sided erosional rills and at top of sea cliffs.
Vegetation	Sparse grass and moderate brush cover.
Approximate natural slope angle range	0° - 5°.
Slopewash development	Little to none.
Soil development	Moderate 5 feet or more thick, reddish and grayish-brown, massive loamy sand and sandy loam with pale-brown and reddish-brown, massive to blocky, sandy loam and sandy clay subsoil, locally calcareous.

LITHOLOGIC FEATURES

Type and color	Grayish-red, reddish-brown, moderate to yellowish-brown and brownish-gray, silty clay, and clayey silt containing some silty sand and sandy silt and gravel.
Bedding	Poorly bedded.
Induration	Poorly indurated and poorly consolidated.
Angularity	Sand and gravel are subangular to rounded.
Sorting	Poorly sorted.
Composition	Clay contains considerable montmorillonite; silt and sand are mostly quartz, feldspars and lithic grains; clasts include quartzite, volcanic rocks and schistose debris from the San Onofre Breccia.
Structure	Flat lying to very gently dipping.
Thickness	As much as 20'.

Contact relations	Unconformable on marine terrace deposits and locally on marine cut terraces in Tertiary formations.
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Age	Upper Pleistocene to Holocene
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ENGINEERING FEATURES

Unified soil classification	CL, ML, minor SM, GC, CM.
Workability	Easily graded.
Slope stability	Fair to poor; locally supports low steep slopes with minor sloughing.
Permeability	Slight to moderate.
Porosity	Moderate to relatively high.
Density	Low to moderate; 75 - 95 P.C.F. dry density.
Expensivity	Moderately to slightly expansive in this quadrangle.
Fabric	Generally massive; surficial cracks similar to moderate jointing due to expansive clays.
Erodibility	Subject to severe rilling and piping.
Other	—

USE POTENTIAL

Sand and gravel	Poor to none due to excessive fines, limited amounts, and location.
Fill	Fair to good for fill; expansive nature may limit use.
Waste disposal sites	Poor, due to limited extent and poor location near seacoast on elevated beaches
Aquifer	Poor.
Other	—

MARINE TERRACE DEPOSITS (Q_{TM})

TERRAIN FEATURES

Topographic expression	Very gently sloping to level bench-like surfaces with some local relief due to scattered sand mounds and steep-sided erosional rills.
Vegetation	Sparse grass and light to moderate brush cover.
Approximate natural slope angle range	0° - 2°.
Slopewash development	None.
Soil development	As much as 20 inches thick, pale-brown, massive to blocky, sandy loam commonly with yellowish-brown, blocky, sandy clay subsoil, locally with pale-brown silty sand subsoil; locally calcareous.

LITHOLOGIC FEATURES

Type and color	Light-brown to yellowish-brown fine sand and silty sand, locally contains gravel especially near the base.
Bedding	Faintly to poorly bedded and crossbedded.
Induration	Loose to locally weakly cemented, poorly consolidated.
Angularity	Subrounded to rounded.
Sorting	Moderately well sorted.
Composition	Quartz and feldspar commonly with lithic grains including schistose debris from the San Onofre Breccia.
Structure	Flat lying to very gently dipping.
Thickness	As much as 50' thick.

Contact relations	Unconformable under nonmarine terrace deposits (Qtn) locally. Unconformable on older sedimentary rock formations; generally flat lying to very gently sloping contacts with local irregularities.
Age	Upper Pleistocene. Abundant molluskan fauna.

ENGINEERING FEATURES

Unified soil classification	SP and SM, minor GP.
Workability	Easily graded.
Slope stability	Poor to fair due to poorly consolidated nature except locally supports low steep slopes where cemented.
Permeability	Moderate to high.
Porosity	Moderate to high.
Density	Low to moderate; 80 - 100 P.C.F. dry density.
Expansivity	Low.
Fabric	Cemented consolidation cracks locally.
Erodibility	High; mostly easily eroded by rilling and locally by winds where uncemented.
Other	—

USE POTENTIAL

Sand and gravel	Poor; limited in quantity; poorly located.
Fill	Good for fill, especially pervious fill, but limited in quantity.
Waste disposal sites	Poor; limited in area, too permeable and poor location near seacoast at high elevation.
Aquifer	Poor; limited in area and thickness.
Other	—

NIGUEL (TN, TNC, TN-SLT)

TERRAIN FEATURES

Topographic expression	Rounded, subdued rolling hills, locally sharply eroded to "badlands" type terrain.
Vegetation	Largely grasses; locally dense brush, especially on exposures in western part of quadrangle.
Approximate natural	10° - 25°; locally steeper, especially where conglomeratic.
Slopewash development	Yields moderately abundant amounts of silty sand slopewash.
Soil development	Relatively shallow due to high rate of erosion.

LITHOLOGIC FEATURES

Type and color	Marine, white to very-light-gray to grayish-yellow fine -to coarse-grained sandstone with interbedded yellow-gray siltstone (Tnslt); basal yellow-brown to pale-reddish-brown conglomerate (Tnc) and light-gray to pale-reddish-brown breccia.
Bedding	Broadly crossbedded with well-bedded interbeds; conglomerates and breccia poorly bedded.
Induration	Friable with well consolidated interbeds; locally moderately well cemented; conglomerate and breccia moderately well consolidated.
Angularity	Subangular to subrounded sand; conglomerate subrounded to rounded; breccia subangular.
Sorting	Poorly sorted sands; well sorted silty sandstone; conglomerate and breccia poor sorted.

Composition	Quartzo-feldspathic sand with abundant biotite especially in silty beds. Siltstone contains variable amounts of montmorillonite and gypsum. Conglomerates contain variable eastern and western bedrock suites in a lithic matrix containing near-shore Pliocene mollusks.
Structure	Gently dipping; jointing minimal.
Thickness	Probably not more than 300' within the quadrangle. As much as 350' regionally (Vedder, et al., 1957).
Contact relations	Lies with angular unconformity on Capistrano and Monterey Formations. Contact relief is as much as 200' within a distance of 3,000' due to broad channeling.
Age and fossils	Contains abundant Pliocene marine mollusks, including the distinctive Pliocene guide fossil <i>Patinopecten healyi</i> (See Vedder 1960). Pholad borings very common.

ENGINEERING FEATURES

Unified soil classification	Mostly SM and SC to GM with interbeds of ML and CL (disaggregated).
Workability	Very easily excavated with light power equipment, except for local well-cemented basal sandstone.
Slope stability	Massive failures rare due to continual rapid erosion and ravelling. Generally low shear strengths.
Permeability	Moderately high except for interbedded siltstones. Lower contacts commonly seep zones.
Porosity	Moderately high.
Density	Medium for sedimentary rocks (95-115 P.C.F.).
Expansivity	Generally low except for clayey silt interbeds which slake readily.

Fabric	Nearly absent except in well-bedded siltstone which is planar parallel to bedding.
Erodibility	High except in siltstone beds which are moderately low.
Other	Some coarse sandstones ravel and rill severely.

USE POTENTIAL

Sand and gravel	Locally clean sand but conglomerates have excessive fines. Generally poor.
Fill	Generally good except for locally friable well-sorted sand which does not readily compact.
Waste disposal sites	Low due to occurrence mainly on topographically high areas and high permeability.
Aquifer	Low due to limited and topographically high occurrence.
Other	—

CAPISTRANO (Tc, Tc-ss, Tc-ss+BC)

TERRAIN FEATURES

Topographic expression	Moderate steepness, well rounded topography, often with sharply incised stream bottoms.
Vegetation	Mainly grasses, and light brush in sheltered canyons.
Approximate natural slope angle range	Ranges mostly between 15° - 30°; steeper on numerous fresh and very old landslide scarps.

Slopewash development	Moderate to slight development of silty clay slopewash.
Soil development	Highly developed cover of dark, grayish-brown adobe. Slopes greater than 27° are generally barren.

LITHOLOGIC FEATURES

Type and color	Marine, yellow-gray to light brownish-gray siltstone with interbedded lenticular white fine-grained sandstone; becomes more sandy in northeasterly exposures where it grades into the Oso Member (See). Uncommon thin pebble sand beds (1' to 3') and thin hard calcareous beds (1' - 4'). Locally distomaceous and tuffaceous. Basal calcareous sandstone (Tc-ss) and sandstone and breccia (Tc-ss+bc) in southwestern area.
Bedding	Mostly poorly bedded to massive. Diatomaceous and tuffaceous units are well bedded and commonly fissile.
Induration	Moderately hard if dry to very soft when wet.
Angularity	Sandstones subangular to subrounded.
Sorting	Very well.
Composition	Quartzo-feldspathic with abundant biotite; montmorillonite clay fraction. Abundant secondary gypsum deposited along joints, fractures, shears and bedding planes.
Structure	Highly jointed and fractured. Mostly poorly developed and commonly much less prominent than jointing. Occupies central portion of the broad Capistrano syncline.
Thickness	As much as 2,100'.

Contact relations	Appears to be gradational on Monterey Formation in most areas; unconformably west of Oso Creek. Overlying Niguel Formation is separated by pronounced unconformity. Grades laterally into Oso Member of Capistrano Formation.
Age and fossils	Contains late Miocene to early Pliocene foraminifera. Megafossils are sparse.

ENGINEERING FEATURES

Unified soil classification	Generally ML, CL to SC, SM (disaggregated).
Workability	Moderately easily excavated with light power equipment but will mire equipment if saturated; local cemented sandstone and breccia commonly require blasting.
Slope stability	Subject to creep, mudflow and landslide on slopes of moderate to high steepness under heavy moisture conditions (see Slope Stability summary). Very low shear strength when saturated.
Permeability	Low except in friable sand lenses where it is moderate.
Porosity	Generally high.
Density	Medium in average material (90 - 110 P.C.F.). Low in diatomaceous-tuffaceous areas (70 - 90 P.C.F.).
Expansivity	High to moderate. Clay fractions have high montmorillonite content.
Fabric	Jointing, spaced at 1' to 3' with locally varying attitudes usually dominant; commonly in two or more directions. Bedding generally is a secondary factor except in diatomaceous-tuffaceous beds.
Erodibility	Fair except for friable sand lenses that ravel and rill severely. Siltstones susceptible to piping.

Other	Calcareous sandstone and breccia facies may pose disposal problems for large boulders.
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USE POTENTIAL

Sand and gravel	None.
Fill	Variable. Clayey materials poor due to expansibility, etc.; diatomaceous materials poor due to low densities. Sandy silts good. In general Tc is more acceptable if blended with sand. Suited for impervious blanket use if high moisture level is maintained.
Waste disposal sites	High, due to ease of excavation, low permeability (Class II, III).
Aquifer	Low.
Other	Soil mantle on Tc may be useful as a topsoil base for large scale landscaping of tracts. Basal sandstone and breccia (Laguna Niguel area) may be used for riprap. Siltstone is mined two miles south of the quadrangle for expanded light-weight aggregate.

CAPISTRANO - OSO MEMBER (Tco)

TERRAIN FEATURES

Topographic expression	Moderately rounded and steep.
Vegetation	Relatively dense brush in uncleared areas.
Approximate natural slope angle range	Mostly 10° to 25°.

Slopewash development	Rapid accumulation of silty sand slopewash which commonly chokes drainages.
Soil development	Moderately deep, well drained, commonly calcareous cover. Sandy loam to clay loam.

LITHOLOGIC FEATURES

Type and color	Marine, white to very-light-gray, medium- to fine-grained silty sandstone with thin shaly silt interbeds, especailly in south and western occurrences.
Bedding	Massive to poorly bedded and broadly crossbedded, also minor thin well bedded shales.
Induration	Well consolidated to friable with common 6" to 1' calcareous concretions.
Angularity	Angular to subangular.
Sorting	Poorly sorted; minor well sorted interbeds.
Composition	Highly feldspathic, quartzose with abundant mica.
Structure	Largely lacking except for thin shaly interbeds. Normally gently dipping.
Thickness	As much as 300' within the quadrangle. Reported to be as much as 1,500' thick along Serrano Creek to the north (Vedder, et al., 1957).
Contact relations	Unconformably or gradationally overlies Monterey Formation. Grades and interfingers with normal Capistrano Formation west of Oso Creek and south of Trabuco Creek. Overlain with angular unconformity by Niguel Formation.
Age and fossils	Interfingers with normal Capistrano Formation containing late Miocene and early Pliocene foraminifera. Megafossils are rare; sharks teeth and marine vertebrate remains are the most common. Contains scant numbers of Pliocene pectens of questionable relationship.

ENGINEERING FEATURES

Unified soil classification	Mainly SP, SW and SM with minor ML <i>when disaggregated.</i>
Workability	Moderately easy to moderately difficult with heavy power equipment.
Slope stability	Very stable for massive failures but prone to mudflow failures near steep heads of canyons during heavy rainfall periods (high incidence of failure during 1969 storms).
Permeability	Highly variable; low to high; generally moderate.
Porosity	Variable but mainly low.
Density	Medium for sedimentary rocks (90 - 115 P.C.F.).
Expansivity	Low.
Fabric	Relatively low fabric resulting from poor bedding. Jointing contributes little effect generally.
Erodibility	Moderately high. Rills and ravel readily.
Other	—

USE POTENTIAL

Sand and gravel	Low.
Fill	Very good.
Waste disposal sites	Good (Class II, III).
Aquifer	Low.
Other	Possible specialty sand source in northernmost exposures.

MONTEREY (Tm, Tm-ss, Tm-Tls, Tm-LS)

TERRAIN FEATURES

Topographic expression	Rounded gently rolling hills; resistant sandstone and limestone beds form bouldery outcrops and small cliffs near stream courses.
Vegetation	Natural vegetation was probably grassland with sparse brush and cactus. Nearly all the outcrop areas are dry-farmed.
Approximate natural slope angle range	Ranges generally from 7° to 20°. Tends to be least on dip slopes; greatest on antidip slopes.
Slopewash development	Thick accumulations on shale and siltstone, chokes canyons and small drainages. These may reach 25' but probably average 5-10' thick. Usually highly plastic clay.
Soil development	Commonly 3-5' thick. Usually highly plastic, expansive dark brown with calcareous subsoil. Clay forms uniform cover in most areas.

LITHOLOGIC FEATURES

Type and color	White to yellowish-gray, siliceous shale and siltstone; minor sandstone (Tm-ss), sandy limestone (Tm-ls) and discordant travertine-limestone (Tm-tls) near the base.
Bedding	Very thinly bedded; locally rhythmically bedded; commonly contorted.
Induration	Moderately well indurated generally; limestone and cemented sandstone interbeds are very hard, resistant materials; shale and siltstone become soft when saturated.
Angularity	Sandstone interbeds subangular.

Sorting	Sandstones are poorly sorted.
Composition	Siltstone and shale; diatomaceous and tuffaceous with minor phosphatic lenses; montmorillonite clay common; minor palygorskite in fractures. Sandstone interbeds; quartzofeldspathic with abundant blue-schist and quartzite lithic grains. Limestone interbeds range from partially recrystallized coquina to travertine.
Structure	Broadly synclinal; gently to moderately east-dipping on the east flank of the San Joaquin Hills and gently west-dipping on the west flank of the Santa Ana Mountains. Many local tight folds. Penecontemporaneous deformation evident.
Thickness	About 1,200' in eastern part and 700' in western part of quadrangle (Smith, 1960, p. 479).
Contact relations	Unconformably overlies Sespe and Vaqueros Formations, San Onofre Breccia and Topanga Formation. Probably locally conformable on San Onofre Breccia. Overlain gradationally by Capistrano Formation; unconformably west of Oso Creek; and unconformably by Niguel Formation and nonmarine terrace deposits.
Age and fossils	Siltstone and shale (the upper part of the formation) contain late Miocene forams (Luisian and Mohnian). Lower section contains sandstone containing megafossils suggestive of slightly older stages. (<i>Pecten crassicaudo</i> and <i>Vaquerosella cf. merriami</i>).

ENGINEERING FEATURES

Unified soil classification	Siltstone and shale, SM, and ML to CL and CH (when disaggregated); sandstones and limestones generally are very hard rock.
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Workability	Siltstone and shale can be removed easily with light power equipment; limestone and sandstone can be removed with difficulty by heavy power equipment and blasting. Siltstone and shale mire equipment when wet.
Slope stability	Siltstone and shale: Very poor; both bedrock and surficial failures are common. Sandstone and limestone: Poor, principally because of associated siltstone and shale. Low shear strength when saturated; high plasticity index.
Permeability	Generally very low.
Porosity	Very high in low density siltstone and shale.
Density	Siltstone shale: Very low; some diatomaceous-tuffaceous shales float on water (50 to 90 P.C.F.); sandstone 110 - 140 P.C.F.
Expansivity	Siltstones-shale; are high; weather to plastic clays which are very expansive.
Fabric	Highly developed due to very thin, fissile bedding and bentonitic layers.
Erodibility	Siltstone and shale erode easily when weathered, but only moderately when fresh.
Other	Siltstone and shale are commonly deeply weathered. Excavations suggest weathered zone averages 50' thick.

USE POTENTIAL

Sand and gravel	None. Limestone and calcite cemented sandstone might be used as riprap.
Fill	Poor to fair for impervious fill. Low compactability.

Waste disposal sites	Good, due to ease of excavation, low permeability (Class II, III).
Aquifer	Poor.
Other	Small bodies of limestone up to 50,000 tons (?) appear to be of very high grade CaCO_3 (93-99%). Low density siltstone and shale may have use as expanded aggregate or absorbent. Abundance of phosphate nodules and thin oolitic shales suggest the possibility of economic phosphate deposits. Some nodules and shale samples contain P_2O_5 (20-40%). Location poor for these uses.

SAN ONOFRE BRECCIA (Tso, Tso-ss, Tso-slt, Tso-d)

TERRAIN FEATURES

Topographic expression	Moderate to steep slopes with rounded hilltops and rounded, narrow steep-sided ridge tops commonly paralleling strike of beds.
Vegetation	Moderate to dense brush; grass and scattered brush on siltstone and diatomaceous shale.
Approximate natural slope angle range	15° - 40°+; some scarps and incised drainage slopes exceed 60°.
Slopewash development	Thin to non-existent, except moderately thick and expansive in areas of siltstone and diatomaceous shale.
Soil development	Thin on most slopes; moderately thick and expansive on gentle slopes developed in siltstone and diatomaceous shale.

LITHOLOGIC FEATURES

Type and color	Marine; locally nonmarine (?) reddish-brown, yellowish-brown, greenish-gray and bluish-gray, sandy to clayey breccia and sandstone (Tso-ss), siltstone (Tso-slt), and conglomerate; minor light-gray to white diatomaceous shale and tuff (Tso-d).
Bedding	Massive to poorly bedded, commonly lenticular with gross variations in structure and material over relatively short distances.
Induration	Moderately well-indurated and cemented; local variations to poorly cemented, especially in deeply weathered areas and in siltstone.
Angularity	Mostly angular to subangular boulders, subangular to subrounded cobbles, subangular to rounded pebbles, and angular to subrounded sand.
Sorting	Mostly very poor with minor areas of fair to good sorting.
Composition	Clasts are quartzite, quartz schist, quartz-albite schist, blue and green schists, saussuritized gabbro. Matrix is quartz, feldspar and lithic grains with silt and clay in the interstices. Cement is calcareous.
Structure	Complex with gentle to steep bedding.
Thickness	At least 500' within quadrangle. 2,600' reported by Woodford (1925, p. 125).
Contact relations	Unconformable on Topanga, Vaqueros, and Sespe Formations; locally interfingers with Topanga and Monterey Formations.
Age and fossils	Locally contains middle Miocene marine fossils, including <i>Balanus</i> , <i>Lyropecten crassicardo</i> , <i>Pecten (Amusium) lompopensis</i> Arnold and, apparently in the upper part of the section, <i>Vaquerosella andersoni</i> .

ENGINEERING FEATURES

Unified soil classification	GC, GM, SC, SM, CL when disaggregated.
Workability	Workable with some difficulty with heavy power equipment; locally requires blasting especially of large unweathered boulders in small or narrow excavations, commonly selective disposal of large boulders and cobbles is required.
Slope stability	Generally good, but fair to poor in local siltstone and diatomaceous shale and tuff beds and sheared zones along major faults, bedding orientation is seldom a strong factor in slope stability in sound breccia and conglomerate facies.
Permeability	Medium to low; especially low where clayey matrix is prevalent.
Porosity	Low to medium; high in local diatomaceous shale and tuff.
Density	Relatively high (110 - 140 P.C.F.); boulders commonly exceed 150 P.C.F. dry density. Low in local diatomaceous shale and tuff.
Expansivity	Low in sandy matrix facies. Moderate in clayey matrix and siltstone facies.
Fabric	Minimal. Reacts massively due to lack of distinct planar structures except for local sheared zones and siltstone facies.
Erodibility	Low, especially in fresh rock, but locally moderate in deeply weathered zones, especially in siltstone and facies with clayey matrix.
Other	—

USE POTENTIAL

Sand and gravel	None; too variable and excessive fines.
Fill	Fair to good for fill except for larger sized boulders and expansive nature of clayey matrix and siltstone facies.
Waste disposal sites	Generally poor, due to rather limited areal extent, proximity to major drainages and somewhat difficult grading properties.
Aquifer	Poor, due to lenticularity of beds and generally low permeability.
Other	Large boulders make excellent decorative landscaping stone.

TOPANGA (T_T, T_T-SLT, T_T-SS, SLT)

TERRAIN FEATURES

Topographic expression	Moderate to steep slopes with narrow steep-sided ridge tops commonly paralleling strike of beds; gentle to moderate slopes in predominantly siltstone areas.
Vegetation	Moderate to sparse brush and light to moderate chaparral. Some oak woodlands, especially in canyons oriented east-west; barren on steep, well cemented sandstone; grasses with light brush on siltstone facies.
Approximate natural slope angle range	15° - 40°+; some cliffs and steeply incised drainage slopes; thick well-cemented sandstone outcrops are nearly vertical for 40 or more feet.

Slopewash development	Thin to sparse in sandstone; thick and expansive in areas of siltstone and thick loose fine silty sand along base of slopes.
Soil development	Generally thin and poorly developed, except on gentle slopes in areas of siltstone where soil is moderately thick and expansive.

LITHOLOGIC FEATURES

Type and color	Marine; yellowish-gray, dusky yellow, pale-yellowish-brown, moderate-yellowish-brown, light-brownish to light-olive-gray fine silty sandstone, locally conglomeratic, and interbedded brownish and olive-gray siltstone (Tt-slt). Interbedded sandstone, siltstone (Tt-slt).
Bedding	Thickly bedded, commonly broadly lenticular, locally medium to thinly bedded.
Induration	Moderately well indurated. Well cemented sandstone predominates with friable sandstone and soft siltstone interbeds.
Angularity	Mostly subangular to subrounded grains with minor subrounded to rounded pebbles and very minor subangular to subrounded cobbles.
Sorting	Moderately well to well.
Composition	Quartz, feldspar, and lithic grains of mainly quartzite and schist with minor hornblende and mica; pebbles are mostly acidic volcanic and plutonic varieties; minor cobbles are commonly blue-schist varieties. Calcium carbonate cementing material. Abundant chlorite.
Structure	Moderate to moderately steep easterly dips north of the Temple Hills fault; gentle to moderate southerly dips south of the Temple Hills fault; moderate westerly dips along the eastern margin of the quadrangle.

Thickness	At least 1,500' in western parts of quadrangle; less than 500' along eastern margin; about 7,000' regionally (Vedder, et al., 1965, Pl. 2).
Contact relations	Probably mostly unconformable with the underlying Vaqueros Formation; locally interfingered and gradational with the generally overlying San Onofre Breccia.
Age and fossils	Contains abundant middle Miocene marine fauna including <i>Balanus</i> , <i>Lyropecten crassicardo</i> , <i>Turritella ocoyana topangaensis</i> , <i>Ostrea titan</i> , <i>Pecten (Amusium) lompocensis</i> Arnold and <i>Pecten vanvlecki</i> , Arnold.

ENGINEERING FEATURES

Unified soil classification	SM, ML, CL with minor GM when disaggregated.
Workability	Commonly workable with minor difficulty with power equipment; locally requires minor blasting in well cemented beds, especially in small or narrow excavations.
Slope stability	Generally good, except in siltstone or interbedded siltstone and friable sandstone beds where slumping and bedding plane slides are fairly common.
Permeability	Medium to low due to appreciable percentage of fines, siltstone interbeds and well cemented beds.
Porosity	Medium in sandstone to relatively high in siltstone.
Density	Moderate to high; most sandstone ranges from 120 - 130 P.C.F. dry density; most siltstone ranges from 90 - 110 P.C.F. dry density.
Expansivity	Low to non-expansive in most sandstone; low to moderate in most siltstone.
Fabric	Minimal to moderate due to generally massive and thickbedding and broadly lenticular zones; locally sheared and jointed.

Erodibility	Low in well cemented sandstone; moderate in friable sandstone and siltstone.
Other	Rockfall hazard in very steep areas of hard sandstone.

USE POTENTIAL

Sand and gravel	Low, silty fine sand plentiful, but very little gravel.
Fill	Good for fill except for rilling tendencies in friable sandstone and expansive character of siltstone character of siltstone derived material.
Waste disposal sites	Generally poor, due to difficult workability, high permeability of fill from sandstone and proximity of Topanga terrain to major drainages.
Aquifer	Fair to poor, due to appreciable fines and lenticularity of beds with interbedded siltstone of low permeability.
Other	—

VAQUEROS (Tv)

TERRAIN FEATURES

Topographic expression	Rounded hills with relatively steep antidip slopes.
Vegetation	Brush, normally with chaparral on steep slopes and in canyons.
Approximate natural slope angle range	Highly variable reflecting variable composition, commonly the steepest angle is 18° on antidip slopes.

Slopewash development	Generally poorly developed except on silty or shaly horizons where it commonly is expansive.
Soil development	Usually less than 2' thick except on silty or shaly horizons where it commonly exceeds 3' of expansive soil. Sandy loam to loam.

LITHOLOGIC FEATURES

Type and color	Marine, pale-yellow-brown to dusky-yellowish-green, silty medium-to coarse-grained arkosic sandstone with siltstone and shale interbeds. Well indurated, calcareously cemented sandstone; occurs in the extreme northwest corner of the area.
Bedding	Massive to thick bedded, except thin bedded silty and shaly horizons comprising less than 10% of the outcrop area.
Induration	Moderate to well indurated. Calcareous sandstone very well indurated.
Angularity	Subangular and subrounded.
Sorting	Predominantly poorly sorted with well sorted interbeds.
Composition	Arkosic sandstones derived from tonalite, acidic metavolcanic and metasedimentary rocks of the Santa Ana Mountains (eastern bedrock complex, Woodford, 1926).
Structure	Faulted blocks commonly dipping homoclinally to the east in western exposures; gently northwest dipping in eastern areas.
Thickness	The estimated maximum thickness is 900' in the vicinity of Moulton Parkway and El Toro Road. This section may be repeated by faulting and was probably an erosional high during Topanga time. Elsewhere in the San Joaquin Hills the maximum thickness reaches 3,800' (Yerkes, et al., 1965, p. A30).

Contact relations	Normally conformably overlies and apparently interfingers with the Sespe Formation and is conformably overlain by Topanga Formation; but west of Moulton Parkway, it is overlain unconformably by San Onofre Breccia or Monterey Formation. In some western areas it is missing from the section and the San Onofre Breccia rests directly on Sespe Formation.
Age and fossils	Contains abundant early Miocene shallow water marine fauna including <i>Turritella Inezana</i> (Conrad), <i>Rapana vaquerosensis</i> (Arnold) <i>imperialis</i> (Hertlein and Jordon) <i>Balanus</i> and <i>Ostrea</i> .

ENGINEERING FEATURES

Unified soil classification	Principally SM, SC and SW with ML and CL common in silty and shaly horizons (disaggregated).
Workability	Easily excavated with power equipment. Local calcareously cemented sandstones and coquina may require blasting.
Slope stability	Generally good, except in shaly or silty horizons which comprise less than 10% of western exposures but are common in eastern parts of the quadrangle.
Permeability	Moderate to impermeable except for several highly permeable sandstones in the vicinity of Moulton Parkway and El Toro Road.
Porosity	Moderate to low.
Density	Moderately dense (100 - 130 P.C.F.) for sedimentary rocks.
Expansivity	Moderate to high in the weathered zone of shaly and silty horizons.
Fabric	Massive to thick bedded except for well bedded shaly and silty horizons.

Erodibility	Low to moderate except sandstones in the vicinity of Moulton Parkway and El Toro Road.
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Other	—
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USE POTENTIAL

Sand and gravel	Low; sands contain significant percentages of fines and only minor gravel. Urbanization has covered much of the outcrop area within the quadrangle.
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Fill	Suitable for pervious or impervious fill depending on horizon being considered, except for calcareous sandstones.
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Waste disposal sites	Low because urbanization covers most potential sites and because of limited areal extent.
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Aquifer	Limited surface outcrops suggest the formation would be a poor aquifer.
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Other	—
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SESPE (Ts)

TERRAIN FEATURES

Topographic expression	Low rounded hills with occasional resistant sandstones or conglomeratic sandstones which commonly form steep slopes.
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Vegetation	Brush and cactus with interspersed grass areas.
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Approximate natural slope angle range	Slopes average 10° with occasional slopes of 25°.
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Slopewash development	Commonly thick; 3-10' accumulations of highly plastic reddish sandy clay on lower slopes and in canyon bottoms.
Soil development	Thinly developed on resistant sandstones and upper slopes. Extensive development to form a broad subdued mantle of highly plastic expansive reddish-brown sandy clay (clayloam) on lower slopes and valleys.

LITHOLOGIC FEATURES

Type and color	Nonmarine, moderate-red to very pale-orange, medium- to coarse-grained clayey and silty arkosic sandstone and minor beds of conglomeratic sandstone and mudstone.
Bedding	Poorly bedded; thick bedded and crossbedded.
Induration	Moderate to well.
Angularity	Mostly subangular sand with well rounded clasts.
Sorting	Poor.
Composition	Conglomerates commonly contain dark multicolored siliceous porphyry and welded tuffs. The sandstone and matrix of conglomerates contain quartzo-feldspathic sandstone and silt with minor amounts of red clay.
Structure	Generally dips homoclinally east. Locally faulted with gouge and slickensides common in the northwest corner of quadrangle.
Thickness	Maximum thickness in the San Joaquin Hills is about 2,500' (Yerkes, et al., 1960). Exposures in the northwest corner of quadrangle are estimated to be 900' to 1,200' thick. This section complicated by faulting.
Contact relations	Basal relationships not observed; in the Santa Ana Mountains the Sespe Formation is transitional with underlying Santiago Formation and interfingers with overlying Vaqueros Formation.

Age and fossils	Late Eocene (?) to early Miocene (Vedder, et al., 1957). This is based primarily on marine mollusks underlying and overlying the Sespe Formation.
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ENGINEERING FEATURES

Unified soil classification	Principally SM and SC commonly with beds of SW, SP and GC (disaggregated).
Workability	Easily removed with power equipment when moist. Heavy duty rippers may be required for "dry" conglomeratic beds.
Slope stability	Moderately high overall, but commonly poor in clayey and silty horizons.
Permeability	Moderate to high with local horizons of low permeability.
Porosity	Moderate to high.
Density	Moderately dense (100 - 120 P.C.F.).
Expansivity	Probably low in fresh unsheared rock, however much of the formation is extensively sheared and weathered and thus tends to be highly expansive; mudstones moderately expansive.
Fabric	Commonly complexly fractured and sheared; slickensides common in most fine-grained beds.
Erodibility	Low to moderate in sandstone and conglomerate.
Other	—

USE POTENTIAL

Sand and gravel	Low because of plastic fines and generally low gravel content.
Fill	Good except for expansive slopewash.

Waste disposal sites	Good (Class II, III).
Aquifer	Moderate to good, because of frequent horizons of permeable sandstones.
Other	Possibly a petroleum reservoir rock.

TABLE 2. UNIFIED SOIL CLASSIFICATION (INCLUDING IDENTIFICATION AND DESCRIPTION)

FIELD IDENTIFICATION PROCEDURES				TYPICAL NAMES		INFORMATION REQUIRED FOR DESCRIBING SOILS		LABORATORY CLASSIFICATION CRITERIA	
(Excluding particles larger than 3 inches and basing fractions on estimated weights)									
GRAVELS	CLEAN GRAVELS WITH FINES (Little or no fines)	CLEAN SANDS (Applicable amount of fines)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	GW	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name, indicate approximate percentage of sand and gravel, max size, angularity, surface condition, and hardness of the coarse grains, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for GW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
COARSE GRAINED SOILS	SANDS (For visual classification, the #2 size may be used as equivalent)	CLEAN SANDS (Little or no fines)	WIDE RANGE IN GRAIN SIZES AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	For undisturbed soils add information on stratification, degree of compaction, cementation, moisture conditions and drainage characteristics	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for GW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	GM	Silty gravels, poorly graded gravel-sand-silt mixtures	EXAMPLE - Silty sand, gravelly, about 20% hard, angular gravel particles 1/8" maximum size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, glacial sand, (SM)	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
HIGHLY ORGANIC SOILS	SILTS AND CLAYS (Liquid limit greater than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	GC	Clayey gravels; poorly graded gravel-sand-clay mixtures	For undisturbed soils add information on stratification, degree of compaction, cementation, moisture conditions and drainage characteristics	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	SW	Well graded sands, gravelly sands, little or no fines	EXAMPLE - Silty sand, gravelly, about 20% hard, angular gravel particles 1/8" maximum size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, glacial sand, (SM)	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	SP	Poorly graded sands, gravelly sands, little or no fines	EXAMPLE - Silty sand, gravelly, about 20% hard, angular gravel particles 1/8" maximum size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, glacial sand, (SM)	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	SM	Silty sands, poorly graded sand-silt mixtures	EXAMPLE - Silty sand, gravelly, about 20% hard, angular gravel particles 1/8" maximum size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, glacial sand, (SM)	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	SC	Clayey sands, poorly graded sand-clay mixtures	EXAMPLE - Silty sand, gravelly, about 20% hard, angular gravel particles 1/8" maximum size, rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, glacial sand, (SM)	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	OL	Organic silts and organic silt clays of low plasticity	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	MH	Inorganic silts, mucous or distasteful fine sandy or silty soils, elastic silts	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	CH	Inorganic clays of high plasticity, fat clays	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	OH	Organic clays of medium to high plasticity	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols
FINE GRAINED SOILS	SILTS AND CLAYS (Liquid limit less than 50)	SILTS AND CLAYS (Liquid limit greater than 50)	WIDE RANGE IN GRAIN SIZE AND SUBSTANTIAL AMOUNTS OF ALL INTERMEDIATE PARTICLE SIZES	PT	Peat and other highly organic soils	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name and other pertinent descriptive information, and symbol in parentheses	D ₅₀ = 0.075 D ₁₀ = 0.075 Between one and 3	Not meeting all gradation requirements for SW	Above 'A' line with PI between 4 and 7 are bordering cases requiring use of dual symbols

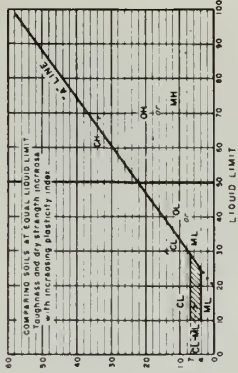
u Boundary classifications - Soils assessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder
 All sieve sizes on this chart are U.S. standard

FIELD IDENTIFICATION PROCEDURES FOR FINE GRAINED SOILS OR FRACTIONS
 These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/4" in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

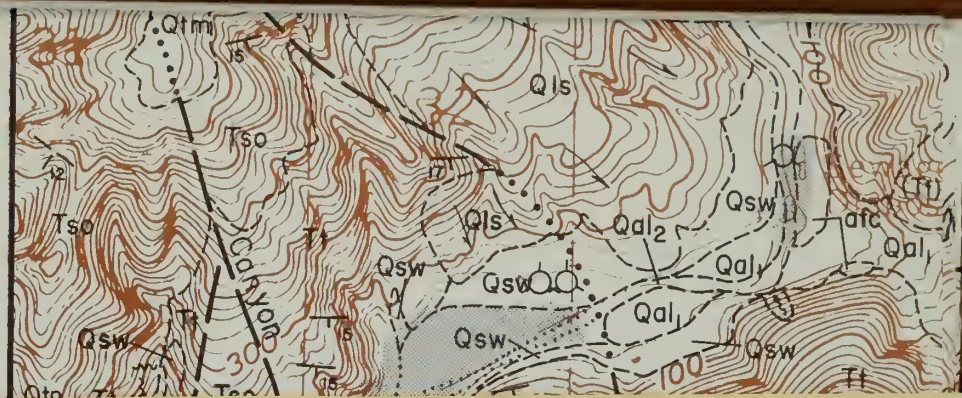
COHESION (Reaction to shaking)
 After removing particles larger than No. 40 sieve size, prepare a moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.
 Place the soil in the open palm of one hand and shake the soil vertically. The reaction consists of the appearance of water on the surface of the soil, which changes to a lumpy consistency and becomes glossy. When the sample is squeezed between the fingers, the water and glass disappear from the surface, the soil stiffens, and finally it cracks or crumbles.
 The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
 Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

DRY STRENGTH (Crushing characteristics)
 After removing particles larger than No. 40 sieve size, mold a ball of soil to the consistency of putty, adding water if necessary. Allow the ball to dry completely by oven, sun, or air drying, and then test its strength by breaking and crushing it. The reaction consists of the appearance of water on the surface of the soil, which changes to a lumpy consistency and becomes glossy. When the sample is squeezed between the fingers, the water and glass disappear from the surface, the soil stiffens, and finally it cracks or crumbles.
 The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
 Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

TOUGHNESS (Consistency near plastic limit)
 After removing particles larger than No. 40 sieve size, a specimen of soil about one-half inch cube in size is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out on a thin layer and allowed to lose some moisture by evaporation. When the specimen is rolled into a thread about 1/8" in diameter, the thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
 After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
 The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more plastic is the colloidal clay fraction in the soil.
 Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay or organic clay. Organic clays such as kaolin-type clays and organic clays which occur below the A-line.
 Highly organic clays have a very weak and spongy feel at the plastic limit.



PLASTICITY CHART
 FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS









GEOLOGIC MAP OF THE SAN JUAN CAPISTRANO QUADRANGLE, ORANGE COUNTY, CALIFORNIA

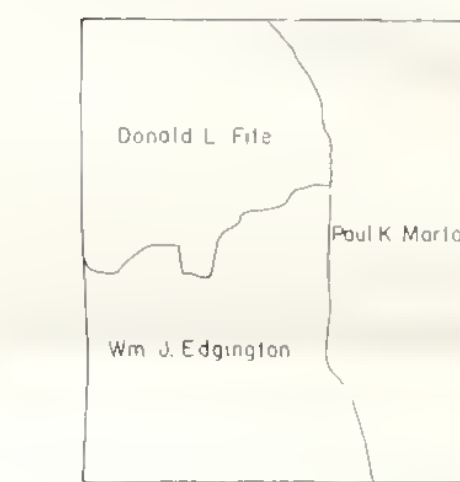
By Paul K. Morlan, William J. Edgington and Donald L. Fife

1974

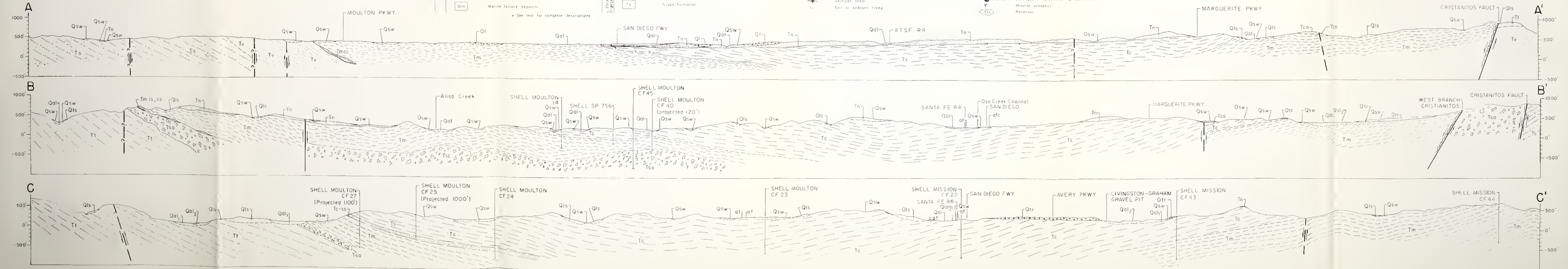
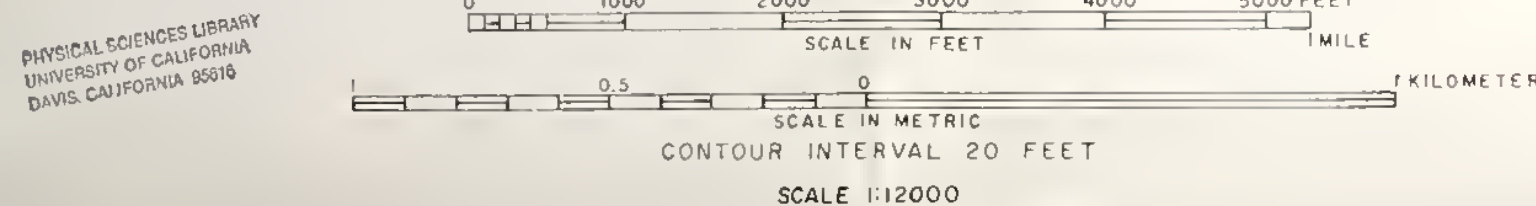
EXPLANATION

SYMBOLS

- Shattered formation designation indicates major geological unit within developed area or isolated exposure within surficial unit.
- Debris or soil flow, limits definable.
- Bedrock landslide, scarp exposed where shown.
- Probable or possible landslide.
- Barely leveling slope.
- Fault scarp.
- Axis of synclinal fold, dashed where approximated.
- Axis of synclinal fold, dashed where approximated.
- Spring or seep.
- Closed depression.
- Exploratory boring drilled for petroleum.
- Exploratory spring drilled for petroleum, converted to water well.
- Exploratory boring drilled for petroleum, converted to water well, flowing water.
- Water well.
- Earthquake epicenter, magnitude, and date.
- Mineral prospect.
- Reservoir.



AUTHOR INDEX OF MAPPING
SAN JUAN CAPISTRANO QUAD



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